

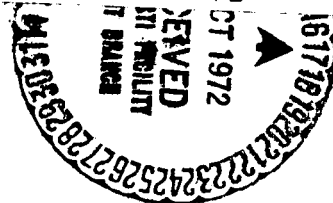
H.J. Lippolt and Gerald J. Wasserburg

(NASA-TT-F-14437) RUBIDIUM-STRONTIUM
MEASUREMENTS ON BOSUMTWI CRATER GLASSES AND
IVORY COAST TEKTITES H.J. Lippolt, et al
(NASA) Jun. 1972 17 p CSCI 03B

Unclas
43372

G3/30

43372



JUNE 1972

RUBIDIUM-STRONTIUM MEASUREMENTS ON BOSUMTWI CRATER GLASSES AND
IVORY COAST TEKTITES

A Rb-Sr isotopic study of 5 glasses from the Bosumtwi crater in Ghana and of three Ivory Coast tektites was made. The Sr^{87}/Sr^{86} ratios for the glasses lie between 0.716 and 0.734 and those for the tektites between 0.721 and 0.726. The ratios of Rb/Sr are between 0.196 and 0.328 for the crater glasses and between 0.197 and 0.287 for the tektites. The Ivory Coast tektites lie in a region of the Sr evolution diagram which is distinctly lower than for the other tektites groups, (ref. 1). The Bosumtwi glasses define an approximately linear array on the Sr evolution diagram which contains the Ivory Coast tektite points. These results show that the Ivory Coast tektites are distinctive from other tektite occurrences and suggest that the glasses and the tektites may represent fusion products of similar material.

The Bosumtwi crater of Ghana lies in pre-Cambrian rocks, a large part of which is definitely older than 1.9 billion years (ref.2). These rocks are divided into three groups: "Tarkwaian" sedimentary rock (quartzite), Birrimian sedimentary and metamor-

phous rock (greywacke, phyllite, slate), and granite whose age lies between that of the sedimentary rocks (ref.3). The formation of the crater itself dates from the Pleistocene and is explained as a gigantic explosion. As cause of this explosion, McClaren suggested already in 1931 the impact of a meteorite (ref. 4). Indications of this are shatter cones in quartzite outcroppings at the Bosumtwi crater (ref. 5) and the highcompression mineral "coesite" in a tuff-like breccia of the crater (ref. 6). Ref. 8 determined low rubidium-zirconium ratios for two glasses found in the breccia of the crater which suggested to ref. 7 that they are not volcanic glasses. Ref. 9 found iron-titanium ores in these glasses, by means of direct-light microscopy, which indicate, as "thermometer minerals", higher formation temperatures than occur in the usual volcanic processes (greater than 1500°C).

Ref. 10 was the first to point out that the Bosumtwi event might have produced the Ivory-Coast tektites found at a distance of 300 kilometers from the crater. These tektites are found in early Pleistocene sedimentary rock. Ref. 8 determined the potassium-argon age of the Bosumtwi glasses as 1.3 ± 0.3 million years which demonstrated that the Bosumtwi event is coincident with the origin of the Ivory Coast tektites (ref. 11). Comparison of the potassium-zirconium, rubidium-zirconium, nickel-iron and chromium-nickel ratios in the glasses and in an ivory coast tektite are also

compatible with this hypothesis (ref 8).

Excursions by Gentner et al. in 1963 and Chao in 1964 furnished amounts of crater glass permitting more detailed measurements (ref. 12).

Gentner et al. demonstrated with the aid of roentgen fluorescence that the Ivory Coast tektite investigated by them had an appreciably smaller rubidium-strontium ratio (0.20) than other tektites (ref. 1) where these ratios lie between 1.1 and 0.44. Their measurements further showed that the rubidium/strontium ratios of the two crater glasses were also low and almost identical with that of the tektite for one of the glasses. This raises the question whether this concordance exists for other Ivory-Coast tektites and whether the $\text{Sr}^{87}/\text{Sr}^{86}$ isotope ratios also indicate an interrelation of crater glass and tektites. If we assume that the crater glasses are actually fusion products of pre-Cambrian rocks whose age did not differ greatly, then this should be reflected in the $\text{Sr}^{87}/\text{Sr}^{86}$ ratios provided the rubidium/strontium ratios of the original rocks were different. The increase of radioactive Sr^{87} during the last 1.3 million years is, however, too small for these specimens to be measured.

For the purpose of answering these questions, we obtained from Gentner (Max-Planck Institute for Nuclear Physics, Heidelberg) two specimens of glass from the Buonim and Ata valley of the crater

and from Chao (US Geological Survey, Washington) a different specimen of glass from the Ata river together with three specimens of Ivory-Coast tektites as well as a specimen of clay slate from the region of the crater. The tektites were designated as 364, 764 and 1064, the crater glass with BCC 8864, and the slate with BCC 964.

EXPERIMENTATION

We determined the rubidium and strontium content of these specimens as well as the $\text{Sr}^{87}/\text{Sr}^{86}$ ratios with the isotope-dilution method by utilizing Rb^{87} and/or Sr^{84} "spike". When using Sr^{84} spike, content and isotope composition can be measured simultaneously (ref. 13). The measurements were carried out with a 30-cm single-focussing mass spectrometer. Ion detection was made with the electron multiplier. The heating-coil material was oxidized tantalum. For the most important specimens, the isotope composition was determined further from a fraction of the non-spiked solution in a separate experiment. All results are standardized for $\text{Sr}^{86}/\text{Sr}^{88}=0.1194$. Determination of rubidium and strontium content is accurate within less than 2% and the $\text{Sr}^{87}/\text{Sr}^{86}$ ratios are accurate within less than 2 parts in 700. All specimens were first washed in dilute hydrochloric acid and subsequently dissolved with perchloric and hydrofluoric acid. The "spike" was then added and the solution evaporated. Separation of rubidium and strontium was made with an ion-exchange

column. Blank tests resulted in 5 and/or 1×10^{-9} g strontium and rubidium. Even in the specimens with low amount and low content, the measured amount was 500 times greater than in the blank test. In order to make our values comparable to those of other laboratories, sea-water specimens from the North Atlantic were measured. We obtained 0.7074 and 0.7086 whereas the mean value of ref. 14 was 0.7093 ± 0.0005 , i.e. our values are slightly below this mean value.

(a) Probe	(b) Ein- wage mg	$\left(\frac{\text{Sr}^{87}}{\text{Sr}^{86}}\right)_c$	Sr ppm	Rb ppm	$\frac{\text{Rb}^{87}}{\text{Sr}^{86}}$
Buonim A	172	0,7327 0,7330 c	236	78,9	0,970
Buonim B	31	0,7252	104	26,1	0,726
	32	0,7249	101	28,7	0,824
Buonim C	191	0,7165	47,2	9,6	0,587
Buonim CG	2120	0,7335	243	79,8	0,951
Ata A	173	0,7168 0,7165 c	349	64,7	0,538
Ata B	196	0,7187	197	38,9	0,572
Ata C I	275	0,7154	349	64,5	0,534
II	244	0,7152	353	65,3	0,535
EKT 364 I	135	0,7222 0,7225 c	305	60,4	0,573
II	120	0,7219	300	59,1	0,570
EKT 764 I	121	0,7260 0,7257 c	257	73,0	0,833
II	57	0,7247	252	73,4	0,842
EKT 1064 I	77	0,7221 0,7210 c	296	58,4	0,573
Tonschiefer	1038	0,7028	523	22,3	0,124

key:

a = specimen

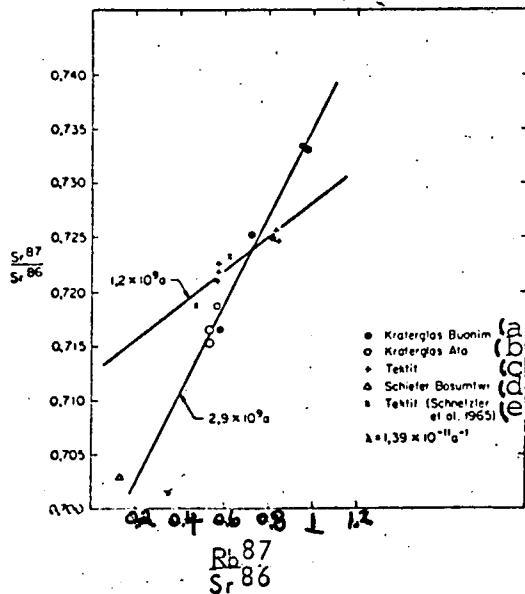
b = weight

c = Ivory-Coast tektite

d = clay slate

Table 1 - Rubidium-Strontium measurement on Bosumtwi glasses and Ivory-Coast tektites.

The findings will be found in table 1 and fig. 1. Fig. 1 is a rubidium-strontium evolution diagram (ref. 15 to 17). Specimens of the same age and same original strontium composition lie on a straight line if they have formed a closed system for rubidium and Sr. The slope of this straight line is a scale for the age of the specimens and the intersection with the $\text{Sr}^{87}/\text{Sr}^{86}$ axis furnishes the original isotope ratio. Fig. 1 further contains two data on Ivory-Coast tektite published in ref. 18.



Key:

- a = Buonim glass
- b = Ata glass
- c = tektite
- d = Bosumtwi slate
- e = tektite (ref.18)

Fig. 1 - The strontium-isotope composition of Ivory-Coast tektites and Bosumtwi glasses.

SPECIMENS

Specimen Buonim-A consisted of a powder (diameter 0.1 mm) obtained by crushing of several pieces of glass with centimeter dimensions and screening out the desired fraction. Any contamination with non-glassy material was carefully avoided. The measurements furnished 236 ppm Sr and 79 ppm Rb. The Rb value is appreciably lower than that of 127 ppm found by Gentner et al. From the new value, there follows a rubidium/zirconium ratio of 0.51 which is now directly compatible with the rubidium/zirconium values for Ata glass and Ivory Coast tektite (0.45 and 0.39). In order to exclude any possible doubt on the true rubidium content, we took a new piece of Buonim glass weighing 2 g which was washed in diluted acid and dissolved (BGG). We obtained 80 ppm of rubidium and 243 ppm of strontium. From polished sections of the non-processed Buonim glass, we found that another rare glassy component exists in the Buonim glass. We therefore attempted separation by specific gravity and found two secondary components in this rock powder: a heavier component (Buonim-B) and about 1%-wgt of a lighter component (Buonim-C) at about 10%.

By crushing another piece of the glass and subsequent gravity separation, we confirmed that this different glass actually was a part of the Buonim glass and not an impurity. These rare glasses

furnish lower rubidium and strontium values and also other rubidium/strontium ratios (factor 1.6). This shows that the Buonim glass on small scale is not homogeneous.

Specimen Ata-A consisted of a coarse (diameter 1 mm) powder of brown-green glass which had been obtained by removing glassy inclusions with centimeter dimensions from the parent breccia. With heavy solutions, it was possible to separate from this a less heavy and lighter fraction: Ata-B.

Specimen Ata-C is the specimen of brown glass found by Chao elsewhere in the Ata valley which we separated under the microscope carefully from nonglassy material. It was shown that this glass has almost the same rubidium and strontium content as specimen Ata-A.

The tektite tests were made by dividing the solutions into two aliquots in order to determine separately concentration and composition from one and only the composition from the other (I). An additional piece of the specimens 364 and 764 was dissolved and the entire solution spiked (II0).

EVAPORATION EXPERIMENT

Of interest in connection with tektite formation is the

question on the extent to which the rubidium/strontium ratio changes under melting and evaporation of silicate material. Several authors (ref. 19-21) had experimentally investigated the evaporation of alkalis under vacuum and under atmospheric pressure. We carried out a brief vacuum experiment. We melted 5.6 g of a microclitic crystal with 558 ppm rubidium and 95.5 ppm strontium and then increased the temperature to about 2000°C. The evaporated material was collected by means of a quartz cylinder projecting above the crucible. The first experiment furnished 510 µg rubidium and, compared to the blank test of this experiment, no strontium (0.5 µg).

The second test on the same material furnished 190 µg of rubidium and again no strontium. The melted material weighed 4.3 g and had a rubidium content of 523 ppm and an Sr content of 93.8 ppm. Whereas the initial material had a rubidium-strontium ratio of 5.84, the melt had a value of only 5.58. Both evaporates must have had rubidium/strontium ratios which were greater than 1160 and/or 442. The experiment indicates that preferential evaporation of rubidium makes a possible isochrone of the melted material steeper. However, this presupposes that the same percentage of rubidium is lost everywhere. On the other hand, an isochrone of the evaporates would be flatter.

DISCUSSION

The strontium-isotope composition of a specimen can be of value if the origin of the material is to be determined. However, the conclusions drawn from this are not necessarily valid as was shown in ref. 22 for carbon.

We restrict our discussion of this question here to the Bosumtwi glasses and Ivory-Coast tektites. It touches, however, also on the results in other tektites obtained by ref. 1.

The Ivory-Coast tektites show a considerable enrichment (3%) of Sr^{87} as compared with a large number of eruptive rock and the initial content of granites during the last two billion years (ref. 23, 24). Preliminary findings in ref. 25 on specimens of obsidian show a rather wide range for the $\text{Sr}^{87}/\text{Sr}^{86}$ ratio but this question has not yet been clarified. Values around 0.725 apparently lie outside of the range found for the initial ratios of eruptive rock which has absorbed no crust material of high age or of high rubidium/strontium ratio (time \times Rb/Sr). As demonstrated earlier in ref. 1, such a ratio is definitely different from that in rock meteorites although a mixture of chondritic and "normal" terrestrial material could have produced such ratios. We therefore conclude from our measurements that the crater glasses and the tektites are fusion products of terrestrial crust material

produced by meteorite impact. The possibility that this fusion process is of volcanic origin appears improbable after the discovery of coesite in one of the crater breccia (ref.6) because it is presently believed that coesite and compression sutures (ref. 5) occur only in meteorite impacts.

A slate specimen from the crater region was measured in order to determine whether it may have been the original material for the glasses. However, the $\text{Sr}^{87}/\text{Sr}^{86}$ ratio (0.7028) was definitely too low. This slate could have been the origin of the crater glasses or tektites only if partial melting of a radioactive phase of the rock had played an important role. A detailed search for other possible initial materials within the Bosumtwi area is urgently necessary.

If the crater glasses and the tektites were the result of complete melting of parts of one rock or of parts of a cogenetic sequence of rocks, then the measured findings should define a straight line in the strontium evolution diagram which established the age of these rocks but not the point in time of the tektite and glass formation. However, since an appreciable fractioning of the elements may have taken place, the findings can be interpreted only with difficulty on the basis of the rubidium-strontium evolution diagram and plotting a straight line through the points by the com-

compensation method may be very misleading (ref. 1). Let us assume that the Ivory-Coast tektites originated through complete fusion of several phases of a number of cogenetic rocks, i.e. without fractioning of rubidium and strontium, we then can state within the limit of error of the analysis that their age should lie between 0.8 and 1.8 billion years. From the findings in ref. 18 this was estimated as 2×10^9 years. On the basis of the same assumptions, a range between 2.4 to 3.2 billion years follows for the crater glasses. Since the points for the Ata glass lie within the range defined by the various Buonim glasses, the above assumption seems satisfied for these two glass finds. However, it should be noted that any possible isochrone through the points of the crater glasses has a very low intersection with the $\text{Sr}^{87}/\text{Sr}^{86}$ axis, e.g. 0.696 for the straight line in the diagram. This value is comparable with that for achondrites and suggests that a chemical process has influenced the gradient of the "isochrones".

Determination of age on post-Birrimian granites and Pegmatites and model ages of galena from the Ivory Coast and Ghana furnished a minimum age of 1.9×10^9 years for the Birrimian sediment (ref. 2,26,27). On the other hand, the Tarkwaian sediments are said to be younger. Although a special examination of age of the Bosumtwi rocks has not yet been made, we may conclude that

our limits of the strontium-model age of the crater glasses are compatible with the regional ages of the Bosumtwi rocks. This demonstrates that these glasses were not formed by any appreciable admixture of young lava with high rubidium/strontium ratio to fused older pre-Cambrian rocks.

The occurrence of different fractions of density in the same specimen of the Buonim glass indicates, together with the appreciable variation of the $\text{Sr}^{87}/\text{Sr}^{86}$ and of the $\text{Rb}^{87}/\text{Sr}^{86}$ ratio, that no homogeneization took place in the formation of the glass, not even on a small scale (less than 1 cm). On the other hand, the material was very well degassed (ref. 8). Examination should be made in any case whether such isotopic inhomogeneities occur also within an individual Ivory-Coast tektite.

The crater glasses and tektites lie in an approximately linear arrangement in the strontium evolution diagram. All $\text{Rb}^{87}/\text{Sr}^{86}$ values are lower than the tektite findings of ref. 12 (minimum factor 1.5) and indicate that the Ivory-Coast tektites are different from other tektites not only in their potassium-argon age but also in regard to the rubidium-strontium factors. Since the scatter of the findings from different specimens lies, however, outside of the experimental error, we cannot conclude that these materials satisfy the prerequisites of a rubidium-strontium

isochrone. However, the result suggests that a genetic relation exists between the crater glasses and the Ivory-Coast tektites.

The tektites may well be fusion products of the same material as the glasses. If the glasses remained closed rubidium-strontium systems during fusion and if the tektites were derived from similar initial substances, we must then assume fractioning of rubidium and strontium in order to explain the deviation of the tektite results from the "isochrone" of the glasses. Accordingly, it is not possible to arrive at more exact conclusions from our measurements in regard to the origin of the Ivory-Coast tektites. However, it has been confirmed that an appreciable similarity exist between the rubidium-strontium relations of the two types of glass.

We are indebted to Professor Gentner and Dr. Chao for furnishing us the material of the specimens and for the discussion of pertinent questions.

The Study was supported by the National Aeronautics and Space Administration (NGR-05-002-028) and a contribution of the National Science Foundation.

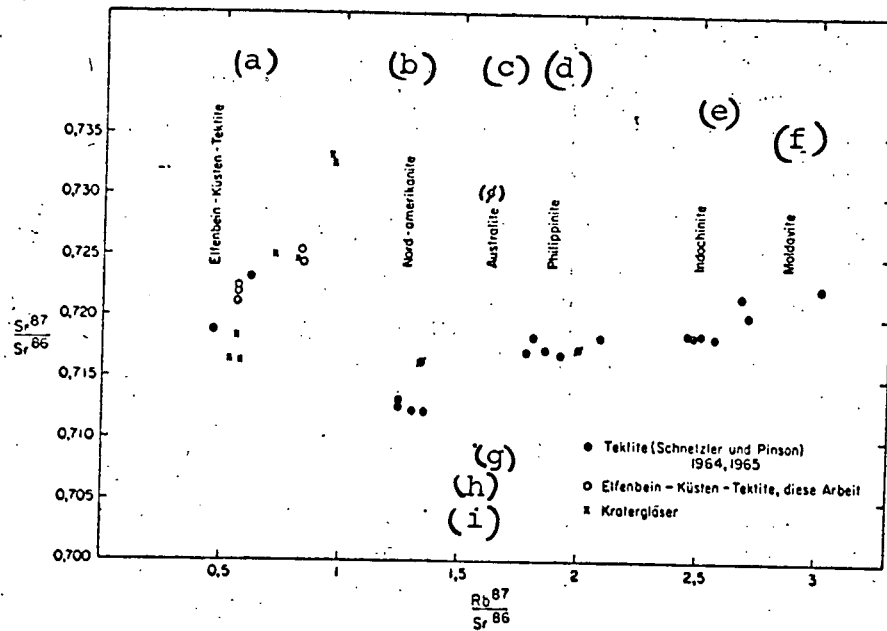


Fig. 2 - Comparison of strontium data for Ivory-Coast tektites and Bosumtwi glasses with other tektites.

key:

- a = Ivory-Coast tektites
- b = North Americanites
- c = Australites
- d = Phillipinites
- e = Indochinites
- f = moldarite
- g = tektites (ref.18)
- h = Ivory-Coast tektites in this study
- i = crater glass

BIBLIOGRAPHY

- ¹ C. C. SCHNETZLER u. W. H. PINSON, *Geochim. Cosmochim. Acta* 28, 953 [1964].
- ² L. CAHEN, *Ann. New York Acad. Sci.* 91, 535 [1961].
- ³ N. R. JUNNER, *Gold Coast Geol. Survey Bull.* 3, 5 [1937].
- ⁴ M. MACLAREN, *Geograph. J.* 78, 270 [1931].
- ⁵ H. P. T. ROHLEDER, *Centr. Bl. Min. Geol. Paläont.* 316 [1934].
- ⁶ J. LITTLER, J. J. FAHEY, R. S. DIETZ u. E. C. T. CHAO, *Bull. Geol. Soc. Amer. Special papers* 68, 218 [1962].
- ⁷ A. SCHÜLLER u. J. OTTEMANN, *Neues Jahrb. Mineral. Abhandl.* 100, 1 [1963].
- ⁸ W. GENTNER, H. J. LIPPOLT u. O. MÜLLER, *Z. Naturforschg.* 19a, 150 [1964].
- ⁹ A. EL GORESY, *Geochim. Cosmochim. Acta* 28, 1881 [1964].
- ¹⁰ A. COHEN, *J. Geophys. Res.* 66, 2521 [1961].
- ¹¹ J. ZÄHRINGER, *Radioactive Dating, Intern. Atomic Energy Agency*, 289, Wien 1962.
- ¹² A. F. C. SMIT, *Nature* 203, 179 [1964].
- ¹³ G. J. WASSERBURG, T. WEN u. J. ARONSON, *Geochim. Cosmochim. Acta* 28, 407 [1964].
- ¹⁴ C. FAURE, P. M. HURLEY u. J. L. POWELL, *Geochim. Cosmochim. Acta* 28, 209 [1965].
- ¹⁵ W. COMPTON u. P. M. JEFFREY, *Nature* 184, 1792 [1959].
- ¹⁶ L. O. NICOLAYSEN, *Ann. NY Acad. Sci.* 91, 198 [1961].
- ¹⁷ M. A. LANPHERE, G. J. WASSERBURG, A. L. ALBEE u. G. R. TILTON, *Isotopic and Cosmic Chemistry 1963*, North-Holland Publ. Company, Amsterdam.
- ¹⁸ C. C. SCHNETZLER, W. H. PINSON u. H. W. FAIRBAIRN, *Trans. Geophys. Union* 46, 118 [1965]. -
A complete report on this study
is to be published in *Science* (1966)
- ¹⁹ I. FRIEDMAN, A. THORPE u. F. E. SENFTLE, *Nature* 187, 1089 [1960].
- ²⁰ J. F. LOVERING, *Nature* 186, 1028 [1960].
- ²¹ L. S. WALTER u. M. K. CARRON, *Geochim. Cosmochim. Acta* 28, 937 [1964].
- ²² H. CRAIG, *Econ. Geol.* 48, 600 [1953].
- ²³ C. FAURE u. P. M. HURLEY, *J. Petrol.* 4, 31 [1963].
- ²⁴ C. E. HEDGE u. F. G. WALTHALL, *Science* 140, 1214 [1963].
- ²⁵ W. H. PINSON u. M. L. BOTTINO, *Geol. Soc. Amer. Program of 1961 Meeting*, 122 A-123 A.
- ²⁶ M. BONHOMME, *Ann. Faculté Sciences de L'Université Clermont*, No. 5 [1962].
- ²⁷ M. VACHETTE, *C. R. Acad. Sci. Paris* 258, 1569 [1964].